



PLASTIC PIER PILING EVALUATION REPORT

Navy Region Southwest

Navy Environmental Leadership Program

Prepared by

Tetra Tech EM Inc.
591 Camino De La Reina, Suite 640
San Diego, California 92108

Contract No. N62474-94-D-7609
Contract Task Order 0244, Subtask 13.6

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EXECUTIVE SUMMARY

In support of the Navy Environmental Leadership Program (NELP), Tetra Tech EM Inc. (Tetra Tech) conducted an evaluation of fiberglass- and steel-reinforced plastic pier pilings installed at five naval installations within Navy Region Southwest, including Naval Air Station North Island, Naval Station San Diego, Naval Amphibious Base Coronado, Space and Naval Warfare Systems Center, and Naval Submarine Base San Diego. Traditionally, treated timber pilings have been used to protect pier structures from impacts of berthing ships. However, because of the environmental concerns associated with leaching of toxic substances from treated pilings and the high maintenance costs associated with replacing untreated timber piles, Navy Region Southwest has been using plastic pier pilings as a nontoxic, long lasting alternative.

Two types of plastic pier pilings have been installed within Navy Region Southwest: fiberglass-reinforced and steel-reinforced. Both types of plastic pier pilings consist of an outer skin of dense plastic and an inner core of foamed plastic encapsulating fiberglass or steel reinforcements. The plastic compound is composed of 100 percent recycled plastic and is designed for its strength and ability to bond with structural elements. The plastic consists of a mixture of high and low density polyethylene and polypropylene obtained from recycled materials such as plastic milk jugs and juice containers. These plastics are mixed with colorants, ultraviolet (UV) inhibitors, and antioxidants, making the product resistant to UV light and spalling, and impervious to marine borers. The reinforcing elements are arranged in a concentric pattern within the inner core of the plastic piling. The type, size, and number of reinforcing elements used depends on the structural requirements necessary for the specific piling application.

This plastic pier piling evaluation focused on assessing the plastic pier pilings' durability, strength, cost, and environmental integrity. The performance of the plastic pier pilings versus timber pilings was evaluated using data provided by plastic pier piling manufacturers, independent laboratory studies, interviews with Navy personnel, and qualitative data generated during field inspections of plastic pier pilings within Navy Region Southwest. Conclusions of the plastic pier piling evaluation are provided below.

Durability. Because use of plastic pier pilings is a relatively recent occurrence, the pilings' long-term durability and maintenance requirements are not known. However, based on the results of this study, the plastic pier pilings appear to be more durable than timber pilings, and the maintenance requirements appear

to be limited. Other than the transverse cracks observed on many of the pilings, plastic pier piling users indicate that they are satisfied with the pilings' performance and have not had maintenance problems. Of the more than 1,200 plastic pier pilings installed during the last 4 years at piers with Navy Region Southwest, none of the pilings has required replacement because of degradation from exposure to the marine environment and fewer than five have required replacement because of ship damage. According to the manufacturers, the plastic pier pilings are warranted against degradation for a period of 10 years and may last as long as 40 years or more if not damaged by berthing ships. Although the actual service life of the plastic pier pilings is unknown, the results of this study suggest that it is longer than untreated and ammoniacal copper zinc arsenate (ACZA)-treated timber pilings, which have a reported life expectancy of 1 to 2 years and 5 to 7 years, respectively.

Strength. The structural properties of the plastic pier pilings can be altered by varying the diameter of the piling and the type, size, and number of structural elements used in the piling. As a result, the plastic pier pilings manufacturers claim that they can design and manufacture pilings to meet the engineering requirements for a variety of piling projects.

Traditionally, timber pilings have been the material of choice for fender pilings because of the high yield stress in bending and relatively low cost of wood. Recently, Navy Region Southwest has been using plastic pier pilings because of their high capacity for energy absorption and the reserve capacity after yield for accidental overload. However, because the structural properties of wood and reinforced plastic are different, the Navy does not consider plastic pilings as a direct replacement for wood. Based on discussions with PWC Waterfront Division personnel, the ductility or lack of stiffness of the fiberglass-reinforced plastic pier pilings installed within Navy Region Southwest has been a concern because highly ductile fender pilings will bend instead of absorbing the lateral load placed on them during berthing of ships. Therefore, fiberglass-reinforced plastic pier pilings installed within Navy Region Southwest have been used primarily as secondary fender pilings.

Navy Region Southwest has recently begun to experiment with steel-reinforced plastic pier pilings as primary fender pilings. According to the manufacturer and tests performed by Navy Facilities Engineering Service Center (NFESC), steel-reinforced plastic pier pilings with a welded steel cage have similar structural properties to those of wood. Fiberglass-reinforced plastic pier pilings can also be manufactured with similar structural properties to those of wood. These pilings combine the stiffness and rigidity of

wood with the reserve capacity after yield of plastic pier pilings. Because steel-reinforced plastic pilings have only relatively recently been installed as primary fender piling, the results of the performance of these pilings are currently not available.

Cost. The costs for installing plastic pier pilings and untreated timber pilings were compared for three cost categories: (1) installation costs; (2) piling costs, and (3) maintenance costs. Installation of timber and plastic pier pilings was estimated to cost \$900 per piling. Untreated timber piling costs were estimated to cost \$1,050 per piling, ACZA-treated timber pilings \$1,580 per piling, and plastic pier pilings from \$2,380 to \$2,730 per piling. Annual piling maintenance costs were estimated to be \$980 for untreated timber pilings and \$350 for ACZA-treated timber pilings. Annual piling maintenance costs for plastic pier pilings assuming a 10 year life expectancy were estimated to range from \$330 to \$360 per piling. Assuming a 40 year life expectancy, annual plastic pier piling maintenance costs were estimated to range from \$82 to \$91 per piling.

Based on the cost data presented above, the initial capital cost to install a plastic pier piling is about \$1,330 to \$1,680 more than the cost of installing an untreated timber piling and \$800 to \$1,150 more than the cost of installing an ACZA-treated timber piling. However, the long-term maintenance costs of the plastic pier pilings are much less. Assuming an estimated plastic pier piling life expectancy of 10 years, the additional cost of installing plastic pier pilings will have a payback of less than 3 years versus untreated timber pilings and a payback of greater than 40 years versus ACZA-treated timber pilings. Assuming an estimated plastic pier piling life expectancy of 40 years, the additional cost of installing plastic pier pilings will have a payback of less than 2 years versus untreated timber pilings and 5 years versus ACZA-treated timber pilings.

Environmental Integrity. Based on toxicity data, the use of plastic pier pilings does not appear to present any environmental concerns to fish and wildlife. Additionally, because the plastic pilings are constructed with inert materials (recycled plastic), there are no additional transportation, use, storage, or disposal requirements.

1.0 INTRODUCTION

This report documents the findings of an evaluation of fiberglass- and steel-reinforced plastic pier pilings conducted at five naval installations within Navy Region Southwest. Traditionally, treated timber pilings have been used to protect the pier from impacts of berthing ships. However, because of the environmental concerns associated with leaching of toxic substances from treated piles and the high maintenance costs associated with replacing untreated timber piles, Navy Region Southwest has been using plastic fender piles as a nontoxic, long lasting alternative.

An evaluation of the effectiveness of using plastic pier pilings was conducted under the Navy Environmental Leadership Program (NELP) in partnership with the Navy Facilities Engineering Service Center (NFESC). Specifically, the pilings' durability, strength, cost, and environmental integrity were assessed using data provided by plastic pier piling manufacturers, independent laboratory studies, interviews with Navy personnel, and qualitative data generated during field inspections of plastic pier pilings installed at five naval installations within Navy Region Southwest. This information was used to compare the performance of various types of plastic pier pilings to each other, and to untreated and treated timber pilings.

This report presents background information on plastic pier pilings, documents the data collection methods and procedures, presents the evaluation results, and draws conclusions based on the information obtained.

2.0 BACKGROUND

This section presents background information on NELP, pier pilings, plastic pier pilings, and key contacts for the evaluation.

2.1 NAVY ENVIRONMENTAL LEADERSHIP PROGRAM

NELP is an initiative established by the Secretary of the Navy to find new and better ways to manage the day-to-day efforts of the Navy's environmental programs. NELP's mission is to serve as a test bed for new and innovative technologies and to provide focused management to address the full spectrum of environmental issues. Successes from the program are exported throughout the Navy. Naval Air Station (NAS) North Island in San Diego, California, and Naval Station Mayport in Florida were selected as NELP bases and are demonstrating innovative technologies and management approaches.

NELP implementation at NAS North Island addresses four key elements of shore station environmental management: cleanup, compliance, natural resources and energy conservation, and pollution prevention. NELP has recently expanded to include information technology projects as well. New projects are selected based on innovation, cost effectiveness, positive return on investment, and potential benefit to other Navy activities. These activities are implemented by establishing partnerships among NAS North Island personnel, the NELP management team, regulatory agencies, and the community.

Recently, the Navy has undertaken a major regional realignment of Naval activities, a process called "regionalization." Most commands in San Diego, including NAS North Island were reorganized on October 1, 1998, to report to the former Commander, Naval Base, San Diego, now called the Commander, Navy Region Southwest. Real estate, real property, and many of the operating budgets formerly assigned to these commands were also reassigned to the new region. Furthermore, similar functions from most commands in San Diego were consolidated into central organizations, each with responsibility on a region-wide basis. As part of regionalization, NELP has expanded from being a Navy initiative at NAS North Island only to a region-wide program, focusing primarily on naval activities within San Diego.

2.2 PIER PILING BACKGROUND

In general, three types of bearing piles are used at piers and wharves: fender piles, structural piles, and group piles. Fender piles are used in front of marine structures to absorb and dissipate the impact energy of ships during berthing. They also provide a barrier to prevent vessels from moving under piers. Structural

piles are used to support the load of light-duty piers and wharves. Structural piling generally uses bracing between piles to increase the strength and stiffness of the foundation for the structure. Groups of piles, known as dolphins, are also commonly placed near piers and wharves to guide vessels into their moorings, to fend them away from structures, or to serve as mooring points. The evaluation described in this document focused on the application of plastic pilings for use as fender pilings.

The Navy uses a number of types of materials for pilings, including concrete, steel, and timber for structural and protective applications of wharves and piers. Because of their high yield stress in bending and relatively low cost, treated timbers have been the preferred material for fender pilings. However, the life span of a treated timber fender piling is commonly less than 5 years because the timber is susceptible to ship damage and degradation. In addition, environmental concerns have been raised over the release of wood preservatives (toxins) from treated timber pilings, in particular from creosote-treated pilings. To address these concerns, creosote-treated timber pilings are no longer being installed within Navy Region Southwest. Instead, the Navy has primarily been using untreated timber pilings and reinforced plastic pilings as fender pilings and, to a lesser extent, timber pilings treated with ammoniacal copper zinc arsenate (ACZA). However, untreated timber pilings are susceptible to degradation and typically have a life span of about 1 to 1½ years.

Currently, the Navy Region Southwest does not consider plastic pilings to be a direct replacement for treated wood fender piles, except for small watercraft piers. Because of the plastic pilings' lack of stiffness, they are not used as fender piles for berthing of large ships. For berthing of large ships, the Navy uses engineered steel or concrete backer pilings and foam-filled fenders, which ride out from the backer pilings. Plastic pier pilings are commonly used as a secondary fender system between the backer pilings to keep floating debris from going beneath the pier.

2.3 PLASTIC PIER PILING DESCRIPTION

In general, two types of plastic pier pilings are available: fiberglass-reinforced and steel-reinforced. Both types of pilings are manufactured using 100 percent recycled plastic and may be a suitable replacement for timber pilings based on the plastic pilings' ability to absorb large amounts of force; plastic piles will deflect

laterally while still offering strong lateral resistance, and spring back into position because of their elastic properties, thus cushioning lateral shocks. The piling's inert construction also minimizes potential environmental impacts and associated regulatory concerns. A description of fiberglass- and steel-reinforced plastic pier pilings is provided below along with general manufacturer claims regarding the pilings.

2.3.1 Fiberglass-Reinforced Plastic Pier Pilings

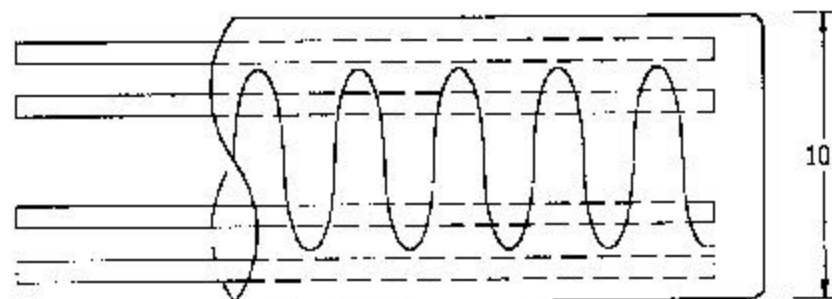
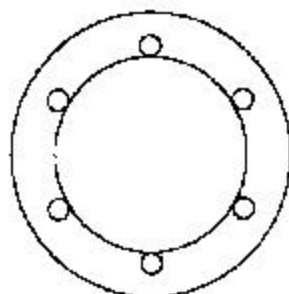
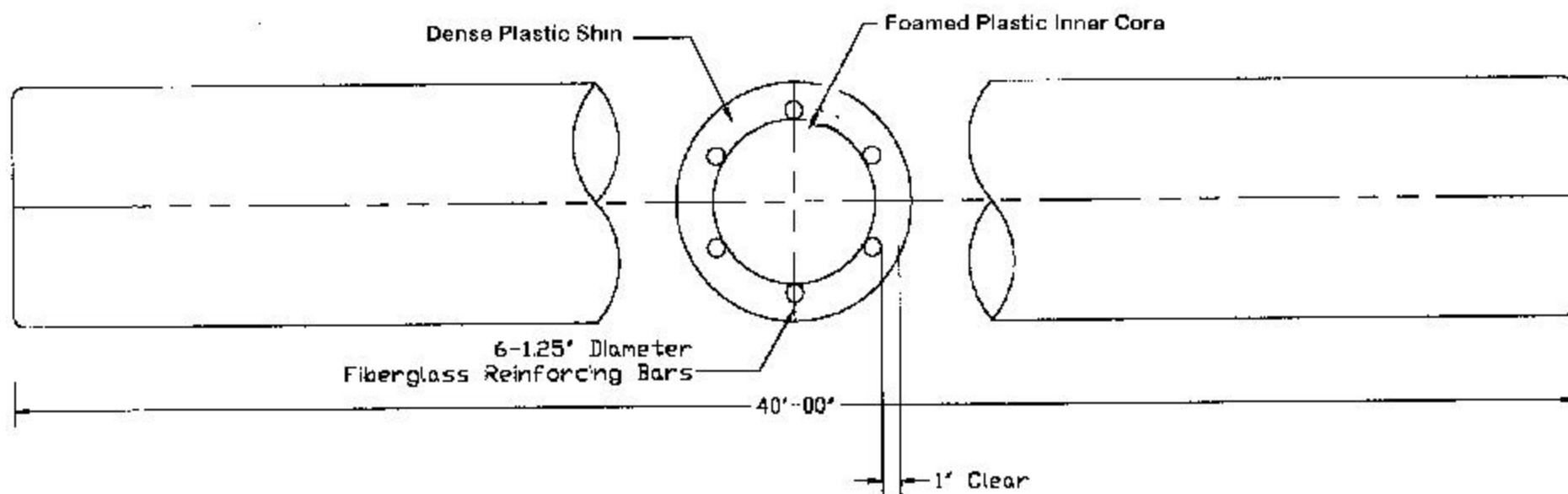
Fiberglass-reinforced plastic pilings consist of an outer skin of dense plastic and an inner core of foamed plastic encapsulating reinforcing fiberglass elements

(see Figure 1). The fiberglass-reinforced plastic pilings are manufactured by Seaward International (Seaward) in a continuous process and Plastic Pilings Inc. (PPI) in a mold-injected process. Both processes were specifically developed for fender piles. Seaward uses a continuous extrusion process and PPI a casting process, both of which result in the pilings having no joints. The plastic compound is composed of 100



Ends of Fiberglass-Reinforced Plastic Pier Pilings

percent recycled plastic and is designed for its strength and its ability to bond with structural elements. The plastic consists of a mixture of high density polyethylene, low density polyethylene, and polypropylene obtained from recycled plastic materials, such as plastic milk jugs and juice containers. These plastics are mixed with colorants, ultraviolet (UV) inhibitors, and antioxidants, making the product resistant to UV light and spalling, and impervious to marine borers. The plastic pilings are reinforced with fiberglass, which makes them noncorrosive. The fiberglass reinforcing elements are arranged in a concentric pattern within the inner core of the plastic piling and extend the entire length of the piling. The size and number of fiberglass reinforcing elements used will vary depending on the structural requirements necessary for the specific piling application.



Unit Weight	CATALOG NO.
2120 lbs	PP-10P#10

DESCRIPTION
10" Diameter x 40' Piling
w/ Fiberglass Cage Reinforcement

Source: Plastic Pilings, Inc. 1995

NAVY REGION SOUTHWEST
PLASTIC PIER PILING EVALUATION

FIGURE 1
FIBERGLASS-REINFORCED



TETRA TECH EM INC.

2.3.2 Steel-Reinforced Plastic Pier Pilings

Two types of steel-reinforced plastic pilings are available: (1) steel pipe core-reinforced plastic piling (see Figure 2), and (2) welded steel-cage-reinforced plastic piling (see Figure 3). The steel-reinforced plastic pilings consist of an outer skin of dense plastic and an inner core of foamed plastic encapsulating the



Welded steel-cage-reinforced plastic pier piling

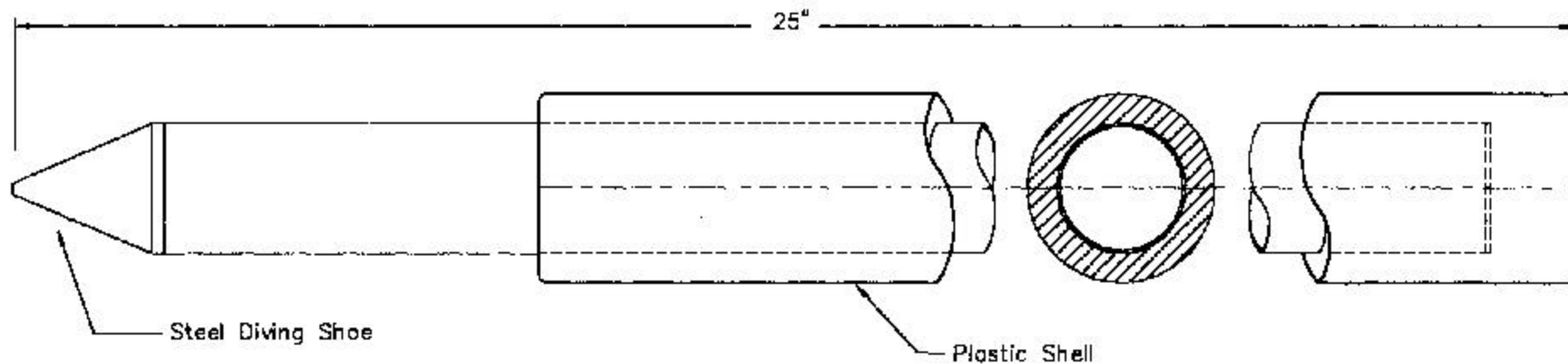
reinforcing steel elements. The steel-reinforced plastic pilings are manufactured by PPI using a casting process, resulting in the pilings having no joints. The pilings are available in sizes from 8 inches in diameter to 36 inches in diameter

with lengths up to 75 feet long. The plastic skin and inner core are composed of 100 percent recycled plastic, which is designed for its strength as well as its ability to bond with structural elements. The

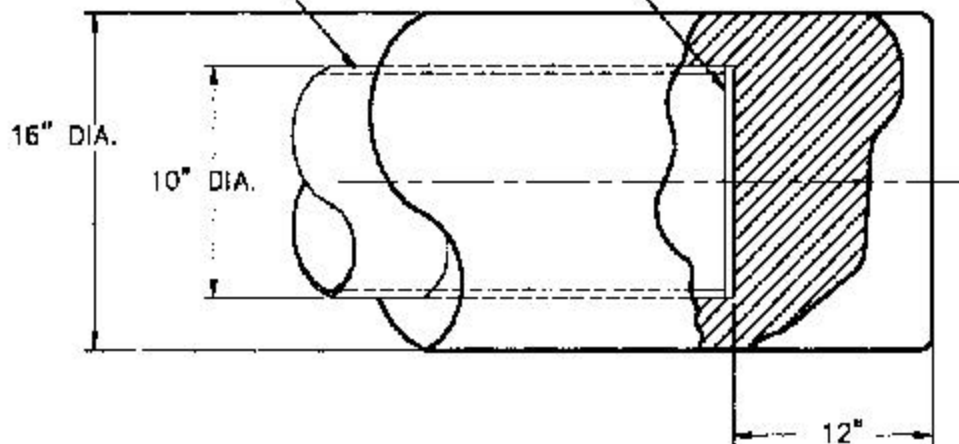
recycled plastic outer shell is made of high density polyethylene, low-density polyethylene, and polypropylene, which are mixed with colorants, flame retardants, UV inhibitors, and antioxidants so that the resulting plastic portion of the product is resistant to UV light, tearing, and spalling, is impervious to marine borers, and will not support a flame. The physical properties of steel-reinforced plastic pilings can be altered by varying the amount of steel in the piling core. For the cage-reinforced plastic pilings, the reinforcing elements are arranged in a concentric pattern within the inner core of the plastic piling, each of which extends the entire length of the piling. For the steel pipe core-reinforced plastic pier pilings, 6- to 28-inch diameter steel pipe cores with a range of wall thicknesses from 0.25 inches to greater than 0.50 inches, extend the entire length of the piling as the reinforcing element.

2.3.3 Manufacturer Claims

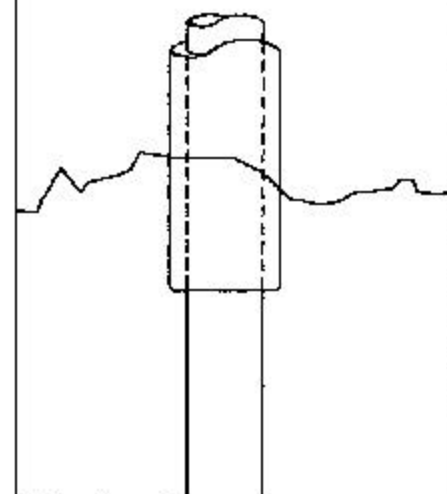
Fiberglass and steel-reinforced plastic pilings are designed for low maintenance. The plastic outer shell has a low coefficient of friction, thus reducing the potential for abrasion of the ship's paint and the



Sch 60 Steel Pipe Core
with Steel End Plate



Plastic to Penetrate
Mud Line Min. 5'



Unit Weight	CATALOG NO.
2325 lbs	PPI16P10

DESCRIPTION

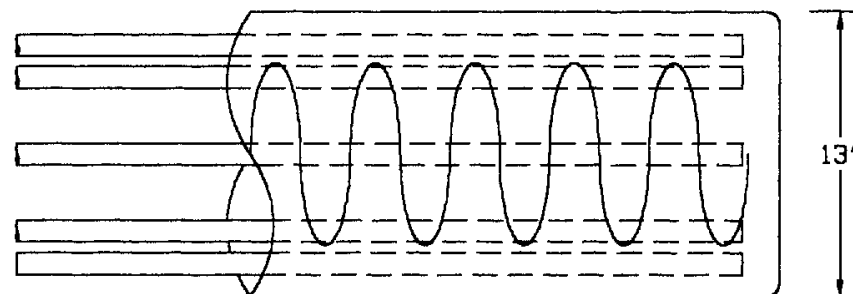
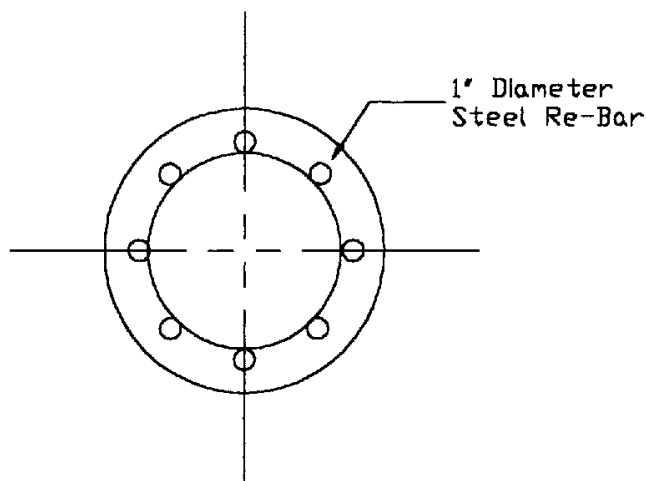
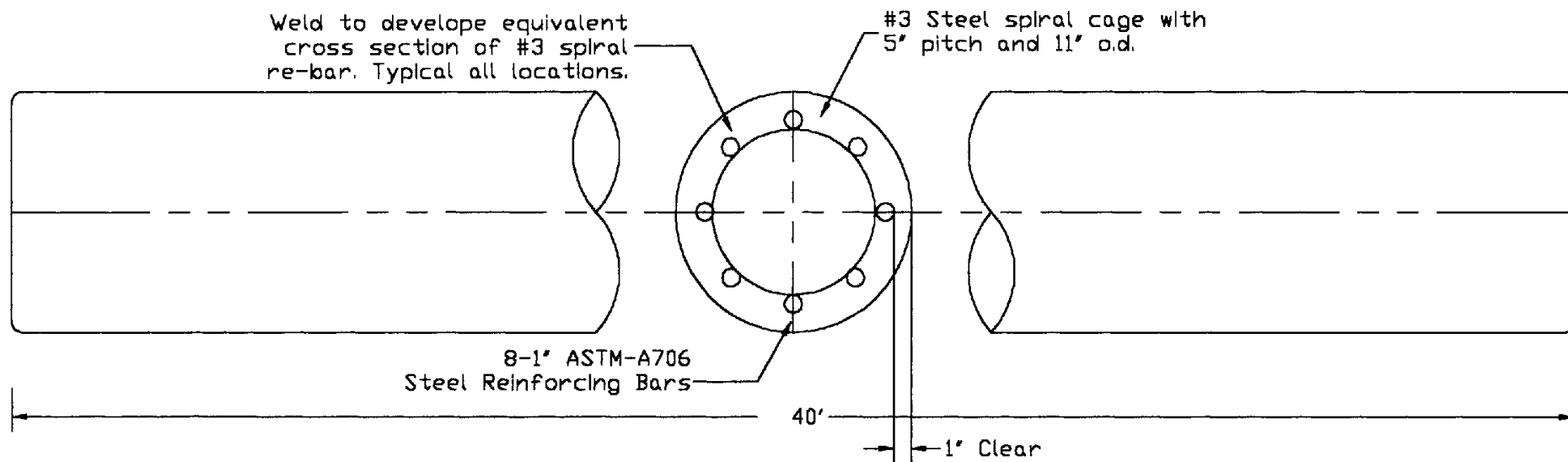
16" Diameter x 25' Piling
Pier 16 NAB San Diego, Ca

NAVY REGION SOUTHWEST
PLASTIC PIER PILING EVALUATION

FIGURE 2
STEEL PIPE CORE-REINFORCED




TETRA TECH EM INC.



Unit Weight	CATALOG NO.
2520	PPI13P#8

DESCRIPTION
13" Diameter x 40' Pilings w/ Steel Cage Reinforcement Pier 160 Spawar USN San Diego, Ca.

Source: Plastic Pilings, Inc. 1998

NAVY REGION SOUTHWEST PLASTIC PIER PILING EVALUATION
FIGURE 3 STEEL-CAGE-REINFORCED
 TETRA TECH EM INC.

piling's surface as well as the lateral load on the piling. The outer shell is repairable if chipped or spalled with a commercially available plastic roofing compound. Significant operational features claimed by the manufacturers of fiberglass- and steel-reinforced pilings include:

- Made from 100 percent recycled plastic
- Impervious to marine borers such as *Teredo*, and *Limnoria tripunctata*
- Immune to marine rot and UV degradation
- Chemically inert in sea water (corrosion-free)
- Has a low coefficient of friction (non-abrasive)
- Does not contain chemical preservatives or creosote
- Will not support fire when flame retardants are incorporated in the material
- Can be made nonmagnetic for electromagnetically sensitive applications
- Can be installed and driven using conventional marine construction methods and hardware
- Can be nailed, screwed, sawed, and drilled
- Maintenance free and graffiti resistant

2.4 KEY CONTACTS

Additional information on the NELP program and this evaluation can be obtained from the NELP Program Manager:

- Mr. Mike Magee
NELP Program Manager
Code N451B
Environmental Business and Technology Office
33000 Nixie Way
Building 50, Suite 322
San Diego, California 92147-5110
Telephone: (619) 524-6357, Facsimile: (619) 524-6519
E-mail: magee.mike.h@asw.cnrsw.navy.mil

Additional information on independent testing of plastic pier pilings can be obtained by contacting NFESC Water Front Materials Division:

- Mr. David Hoy
Naval Facilities Engineering Service Center
Shore Facilities Department
Water Front Materials Division
560 Center Drive
Port Hueneme, California 93043
Telephone: (805) 982-1062, Facsimile: (805) 982-1074
E-mail: hoyde@nfesc.navy.mil

Additional information on the installation and maintenance requirements associated with plastic pier pilings within Navy Region Southwest can be obtained by contacting the Navy Public Works Center (PWC), Waterfront Maintenance Division:

- Mr. Doug Melland
Waterfront Maintenance Division
Navy Public Works Center
2730 McKean Street, Code 543
Building 3213
San Diego, California 92136-5294
Telephone: (619) 556-8860, Facsimile: (619) 556-9380

Additional information on plastic pier pilings can be obtained from the manufacturers:

- Andrew Barmakian
Plastic Pilings Inc.
1485 South Willow Avenue
Rialto, California 92376
Telephone: (909) 874-4080, Facsimile: (909) 874-4860
E-mail: ppi@plasticpilings.com
- Alan Potts
Seaward International, Inc.
3470 Martinburg Pike
P.O. Box 98
Clearbrook, Virginia 22624-0098
Telephone: (540) 667-5191, Facsimile: (540) 667-7987
E-mail: mail@seaward.com

In addition, information on NELP is available on the internet at the following web address:

<http://nelp.navy.mil>

3.0 SITE BACKGROUND, DEMONSTRATION OBJECTIVES, AND DEMONSTRATION METHODS AND PROCEDURES

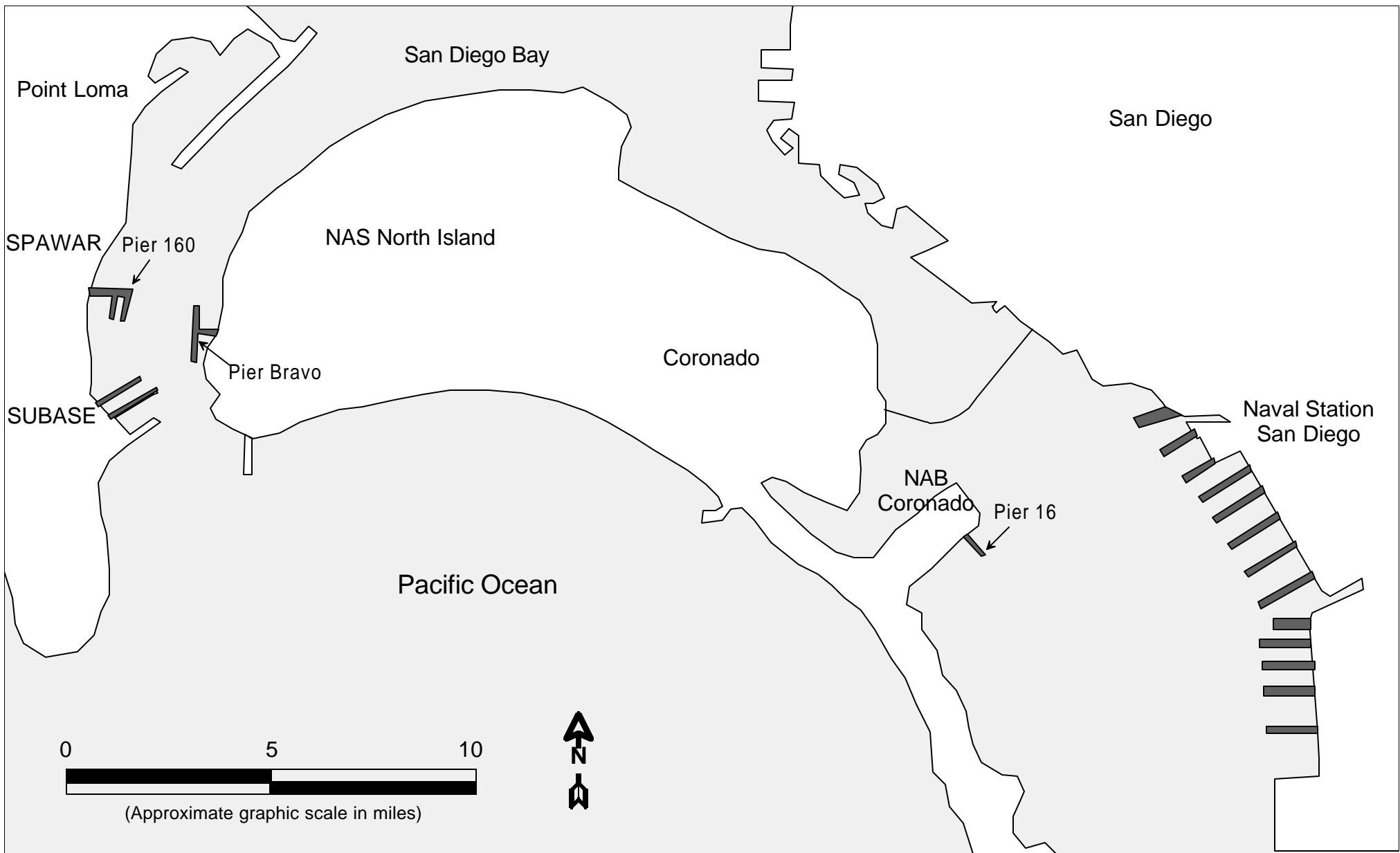
This section provides information on the site as well as demonstration objectives and procedures.

3.1 SITE BACKGROUND

To date, plastic pier pilings manufactured by both Seaward and PPI have been installed at five naval installations within Navy Region Southwest, including NAS North Island, Naval Station San Diego (NAVSTA), Naval Amphibious Base (NAB) Coronado, Space and Naval Warfare Systems Center (SPAWAR), and Naval Submarine Base (SUBASE) San Diego (Figure 4). The plastic pier pilings installed at these bases include both fiberglass- and steel-reinforced plastic pier pilings. The majority of plastic pier pilings installed at the bases are being used as secondary fender piles to protect pier structures from impacts of small ships and to keep floating debris from going under the piers. However, steel-reinforced plastic pier pilings have been installed on several piers as primary fender pilings. The installations at each of the bases is described below.

NAS North Island — Pier Bravo. As part of this demonstration, 12 welded steel-cage-reinforced plastic pier pilings manufactured by PPI were installed in December 1995 at Pier Bravo at NAS North Island. Pier Bravo is part of the Navy Weapons Center at NAS North Island and is located at the southwest corner of the base along the inlet from the Pacific Ocean to San Diego Bay (Figure 4). Pier Bravo is used by the Weapons Center for the loading and unloading of munitions and explosives. As such, the pier is used extensively by a variety of vessels. However, because the pier is exposed and susceptible to strong winds and currents, the largest vessel typically using the facility is the 18,000-ton AD Class destroyer tenders. According to Weapons Center personnel, typically two to three ships berth at the pier every week.

The 12 welded steel-cage-reinforced plastic fender pilings were installed in the mid-section of the pier, which sustains frequent impacts from berthing ships. The pilings were installed as a complete section, spaced approximately 7 feet apart. The remainder of the pier's fender piles consist of timber pilings, also spaced approximately 7 feet apart. Horizontal timber pilings, known as camels, are also used to protect



NAVY REGION SOUTHWEST
PLASTIC PIER PILING EVALUATION

FIGURE 4
PIER LOCATION MAP



TETRA TECH EM INC.

the fender pilings and to distribute lateral loads from berthing ships. According to Weapons Center personnel, foam-filled fenders are also used during berthing of large ships.

Naval Station San Diego — Piers 1, 2, 5, and 8. NAVSTA is located on the eastern portion of the San Diego Bay (Figure 4) and has been used for shipping-related activities for more than 50 years. The piers (see Figure 4) receive heavy use from a variety of ship docking and repair activities. NAVSTA is the home port for a variety of ships, including Aegis Class destroyers. NAVSTA has replaced the majority of timber fender pilings on their piers with fiberglass-reinforced plastic pier pilings and is the largest user of plastic pier pilings within Navy Region Southwest. Since 1995, more than 1,100 plastic pier pilings have been installed at NAVSTA piers, primarily as secondary fender pilings. The plastic pier pilings are typically spaced approximately 16 feet apart and are outfitted with camels to limit floating debris from going beneath the piers. Because of the size of ships berthing at NAVSTA, primary fendering at the piers is conducted using foam-filled fenders such as SEA GUARD® marine fenders, riding out in front of steel or concrete backers.

Space and Naval Warfare Systems Center — Pier 160. As the first part of a 5-year retrofit program, about 80 welded steel-cage-reinforced plastic pier pilings have recently been installed at SPAWAR Pier 160. Pier 160 is part of SPAWAR's Bayside research and development facility on Point Loma, which is located on the north side of the inlet from the Pacific Ocean to San Diego Bay (Figure 4). Pier 160 is used by a variety of research ships for loading supplies and long-term berthing. The initial installation of steel-reinforced plastic pier pilings has been completed along the southern bayside exposure and these pilings act as primary fender pilings to protect the pier. Within 5 years, it is anticipated that all timber pilings at Pier 160 will be replaced with welded steel-cage-reinforced plastic pier pilings.

Naval Amphibious Base Coronado — Pier 16. NAB Coronado Pier 16 is a small finger pier that was outfitted with steel pipe core-reinforced plastic pier pilings in 1996. NAB Coronado is located on the western side of the San Diego Bay, across from NAVSTA (Figure 4). Piers at the base are used primarily by a variety of small watercraft. The 28 steel-reinforced plastic pier pilings at Pier 16 were installed as primary fender pilings. However, ship berthing at the Pier 16 is infrequent and is limited to barge loads.

Naval Submarine Base San Diego — North and Middle Piers. About 50 fiberglass-reinforced plastic pier pilings were installed in 1996 as secondary fender piles at the North Pier and portions of the Middle Pier at the SUBASE. The SUBASE is located along the western side of the inlet from the Pacific Ocean to San Diego Bay (Figure 4). The piers are primarily used by submarines and other smaller support vessels.

3.2 DEMONSTRATION OBJECTIVES

The demonstration was designed to address primary and secondary objectives selected for evaluation of plastic pier pilings. These objectives were selected to provide potential users of plastic pier pilings with the necessary technical information to assess the applicability of the pilings to other sites. For the NELP demonstration, four primary and five secondary objectives were selected and are summarized below:

Primary Objectives

- P1 Evaluate the durability of the plastic fender pilings
- P2 Document the alternative plastic fender pilings' structural properties as measured in the laboratory
- P3 Estimate the capital and maintenance costs of replacing a single treated timber piling with a plastic fender piling
- P4 Assess the pertinent federal, state, and local environmental regulatory requirements related to the transport, use, storage, and disposal of plastic pilings and their residuals

Secondary Objectives

- S1 Document plastic fender piling installation and finishing parameters
- S2 Estimate assets (equipment and parts) that port operations must store and maintain as a result of using alternative plastic fender pilings
- S3 Assess the availability of plastic fender pilings
- S4 Document the potential for plastic fender pilings to reduce wear or adverse impacts on the special coatings of ship hulls

- S5 Document the frequency and degree of maintenance required for upkeep of the plastic pilings

To meet the demonstration objectives, data were collected using the methods and procedures summarized in Section 3.3.

3.3 DEMONSTRATION METHODS AND PROCEDURES

This section describes the methods and procedures use to collect and analyze data to evaluate the use of plastic pier pilings. Data were collected in accordance with the procedures outlined in the Draft Test Plan, Alternative Plastic Pier Piling Demonstration at Pier Bravo, Naval Air Station North Island, dated March 31, 1995 (Tetra Tech 1995). The methods and procedures outlined in the draft test plan were modified to include data obtained from plastic pier pilings installed throughout Navy Region Southwest, including NAS North Island, NAVSTA, SPAWAR, NAB Coronado, and SUBASE. The activities conducted to achieve the demonstration objectives included: (1) collecting manufacturers' data, (2) reviewing independent laboratory engineering studies on plastic pilings, (3) conducting interviews with Navy Waterfront Maintenance personnel, and (4) conducting site inspections to document piling installation and long-term performance.

3.3.1 Manufacturers' Data

An internet search was conducted to identify manufacturers of plastic pier pilings. Two manufacturers were identified that provide plastic pier pilings: (1) Seaward and (2) PPI. Seaward and PPI were contacted to obtain product information, including handling and installation requirements, as well as engineering parameters and analytical test results for the pilings.

3.3.2 Laboratory Studies

Engineering studies conducted for Seaward and PPI by Lehigh University (Lehigh 1995) and Moffatt & Nicol Engineering (Moffatt & Nichol 1998) were reviewed. In addition to engineering studies conducted for

Seaward and PPI, independent engineering studies conducted by NFESC were also reviewed (NFESC 1996). These independent engineering studies were used to verify manufacturer claims regarding the physical properties of the pilings, such as the elastic modulus, maximum bending stress, stiffness, UV degradation, abrasion resistance, and water absorption.

3.3.3 Interviews

Navy and manufacturer personnel associated with design, installation, and maintenance of plastic pier pilings were contacted to obtain information on piling performance. Personnel contacted included PWC Waterfront Division, Navy Region Southwest Water Program, individual base facility and maintenance personnel, and piling manufacturers.

3.3.4 Plastic Pier Piling Inspections

Field inspections of the plastic pilings were conducted during installation and maintenance of the pilings. During piling installation, activities including site preparation, permitting and regulatory review, installation and finishing of the plastic fender pilings, and waste disposal were documented. Additionally, baseline piling conditions were documented to provide a comparison to demonstration inspection data on piling durability.

Maintenance inspections of the plastic pier pilings included visual observation of degradation or physical damage. The observations documented during the piling inspection were compared to timber pilings to provide relative data on the plastic pilings performance under a variety of conditions. Any potential long-term maintenance requirements were also documented during the inspection.

4.0 RESULTS AND DISCUSSION

This section presents the results of the plastic pier piling evaluation within Navy Region Southwest. The demonstration results have been supplemented by information collected by NFESC and information provided by the piling manufacturers. The results are presented by project objective and have been interpreted in

relation to each objective. The specified primary and secondary objectives are shown at the top of each section in italics followed by a discussion of the objective-specific results.

4.1 PRIMARY OBJECTIVES

Primary objectives were considered critical for the evaluation of the plastic pier pilings. Four primary objectives were selected for the demonstration. The results for each primary objective are discussed in the following subsections.

4.1.1 Primary Objective P1

Evaluate the durability of the plastic fender pilings.

The durability of the plastic fender pilings was evaluated by periodically inspecting plastic pier pilings and timber pilings for visible signs of degradation (corrosion, deterioration caused by UV light, and the presence of marine borers) and physical damage (ship damage, abrasion, chipping, and spalling). Visual observations of the plastic pier pilings and timber fender pilings in the same vicinity were compared to provide relative data on the plastic pier piling's durability. A description of the observations at each installation site evaluated during the study is provided below.

NAS North Island. Twelve welded steel-cage- reinforced plastic pier pilings manufactured by PPI were installed at NAS North Island, Pier Bravo in December 1995. Since their installation in December 1995, the plastic pier pilings at Pier Bravo have been inspected twice. The first inspection was conducted by PWC divers on December 19, 1996, about 1 year after the pilings were installed, and included a visual inspection of the piling above and below the water surface. During this initial inspection, PWC reported that all 12 pilings were generally in excellent condition. Two of the pilings exhibited small rub spots, which were considered superficial in nature, and likely would not affect the performance of the pilings. The second inspection of the plastic pier pilings at Pier Bravo was conducted by Tetra Tech on July 19, 1999, approximately 3½ years after the pilings were installed, and was limited to inspection of the pilings above the

water surface. During the second inspection of the pilings, heavy accumulations of barnacles, mussels, and marine algae were observed on the plastic pier pilings, with the heaviest accumulation

occurring in the tidal zone. Abrasions were also observed on the plastic pier pilings where the wood camel rubbed along the front of the piles. However, timber fender piles observed in the immediate vicinity of the plastic pier piling showed significantly more wear and abrasion than the plastic pier pilings, likely due to the

camel riding along the front of the timber piles. A heavy accumulation of marine organisms was also observed growing on the timber piles. Several of the timber pilings in the vicinity of the plastic pier pilings also showed indications of degradation within the tidal zone such as partial deterioration and structural decay of the piling. In other areas of the pier, timber fender pilings were observed to be missing, apparently having rotted away to just below the water surface.



PPI Plastic Pier Pilings Installed at Pier Bravo

During the July 1999 inspection, the two northern-most plastic pier pilings appeared to be permanently deformed. Both pilings were bent about half way between the top of the piling and the water surface with maximum deflection of about 1 foot inwards, towards the pier. At the time of the inspection, only eight of the plastic pier pilings were protected by a camel; the four northern-most plastic pier pilings, including the two deformed piles, were unprotected. The likely cause of the deformation was the loading of the plastic pier piling beyond its elastic limit from the impact of a berthing ship. It is likely that without the protection of a camel riding out in front of the two pilings, a berthing ship directly hit the fender pilings. According to Joseph Shelton, Pier Maintenance Manager, no documentation of the event was recorded. Although the two piles are permanently deformed, they still appear to be functional and showed no other visual signs of damage. Several timber fender piles in the immediate vicinity of the plastic pier pilings also showed indications of ship damage such as scour marks and scrapes as well as cracked and broken piles.

Naval Station San Diego. Starting in 1995, more than 1,100 plastic pier pilings were installed at NAVSTA piers. The majority of these piles are fiberglass-reinforced plastic pier pilings manufactured by Seaward.

The fiberglass-reinforced plastic pilings at NAVSTA are used primarily as a secondary fender system. As such, the amount of wear exerted on the plastic pier pilings is limited to tidal movement of the camel up and down along the front of the pilings and the occasional impact of berthing ships. According to PWC Waterfront Maintenance personnel, fewer than five of the plastic pier pilings installed at NAVSTA have required replacement because of ship damage and none has required replacement because of degradation.

The fender pilings at NAVSTA are periodically inspected by PWC. Typically, fender pilings are only inspected when they have sustained damage or need replacement. However, in July and August 1998, PWC conducted an inspection of more than 300 plastic pier pilings at NAVSTA because of a structural concern over the presence of transverse cracks in the outer matrix of many of the fiberglass-reinforced plastic pier pilings. Of the more than 300 plastic pier pilings inspected, 87 exhibited transverse cracks perpendicular to the long axis of the piling. According to Seaward, the transverse cracks were caused by a defect in the manufacturer's process, which has since been corrected. To evaluate the structural integrity of the cracked piles, Lehigh University's Fritz Engineering Laboratory conducted a flexural test on the cracked piles. According to the structural report prepared by Lehigh University, the data indicated that the cracked pile exhibited "no significant difference in pile deflection or stiffness" when compared to uncracked pilings (Lehigh 1995). The study further suggests that the matrix cracks on the have



Stockpiled Cracked Pilings

no measurable influence on the overall flexural behavior of the piling. Although the manufacturer claims that the structural integrity of the fiberglass-reinforced pilings is not adversely impacted, they have offered to replace the cracked pilings.

Space and Naval Warfare Command Center.

A fender pilings retrofit project was initiated in June 1999 to replace timber fender pilings at SPAWAR Pier 160 with welded steel-cage-reinforced plastic pier pilings manufactured by PPI. The retrofit project has been divided into five phases to spread the capital costs over time. SPAWAR anticipates completing one phase every year during the next 5 years. For the retrofit project, a welded steel cage was selected as the structural element to provide increased rigidity to the piles. The steel-reinforced pilings are being used as the primary

fender system for the pier. According to PPI, their welded steel cage-reinforced plastic pier pilings have been designed to have structural properties similar to timber piles with regard to rigidity and bending moment capacities.

According to David Willis, the SPAWAR Facility Manager, Pier 160 is used frequently by a variety of research vessels. Because of the heavy use, the timber fender piles have sustained significant wear and require replacement as often as every 1 to 2 years. During inspection of the fender pilings at Pier 160 on June 29, 1999, installation of the plastic pier pilings under phase 1 of the retrofit project was almost complete. The newly driven plastic pier pilings appeared in excellent condition with no indications of damage during installation. Heavy marine growth was observed on the timber fender piles along the pier. Several of the timber piles located in the vicinity of the plastic pier pilings also appeared to have significant degradation at the water line and several others were broken from apparent ship impacts.

Naval Amphibious Bases Coronado. Steel-reinforced plastic pier pilings manufactured by PPI were installed at Pier 16 at NAB Coronado in May 1996. Pier 16 is a small finger pier, and the fender pilings installed were designed for barge loads. To sustain barge loads, 16-inch-diameter plastic pier pilings with 10-inch-diameter, schedule 60 steel pipe core were used. Twenty four-inch diameter camels also manufactured by PPI from recycled plastic were also installed along the fender piles. Reportedly, ship berthing at the pier is infrequent and the pilings have a low potential to sustain ship damage. According to Vergil McCallaster, the NAB Coronado Facilities Manager, the plastic pier pilings are still in excellent condition, while many of the untreated timber piles at NAB Coronado installed around the same time have required replacement. Mr. McCallaster indicated that ACZA-treated timber pilings had also been installed within the last year at several of the piers at NAB Coronado. However, the condition of these treated pilings was not evaluated during this study.



Steel-Reinforced Plastic Pier Pilings Installed at NAB Coronado Pier 16

Naval Submarine Base San Diego. Plastic pier pilings were installed at the North Pier and portions of the Middle Pier at the SUBASE in 1996. The plastic pier pilings are being used as a secondary fender system for the piers. According to David Hoy, NFESC Waterfront Division, the SUBASE is also conducting an evaluation of concrete-filled composite fender piles. During a limited inspection of the plastic pier pilings on the North Pier on August 9, 1999, the pilings appeared in good condition with moderate amounts of marine growth in the tidal zone. No visual indications of degradation or significant ship damage were observed. However, the pier is used primarily by submarines and the primary fendering system at the pier significantly limits the potential for impacts on the secondary plastic fender pilings.

4.1.2 Primary Objective P2

Document the alternative plastic fender pilings' structural properties as measured in the laboratory.

The strength of the fiberglass- and steel-reinforced plastic pier pilings as measured in the laboratory was documented during the evaluation. Both Seaward and PPI have conducted laboratory studies and have hired engineering firms to evaluate the structural properties of their plastic pier pilings. In addition, the Navy has conducted several independent engineering studies to evaluate strength of the pilings.

Parameters that were evaluated include modulus of elasticity, maximum yield stress in bending, compressive modulus, moment of inertia, stiffness, weight, and specific gravity.

The structural properties of the plastic pier pilings can be altered by varying the diameter of the piling and the type, size, and number of structural elements used in the piling. As such, Seaward and PPI claim that they can design and manufacture pilings to meet the engineering requirements for a variety of piling projects. A comparison of select engineering parameters is presented in Table 1 to provide an indication of the relative strength of each piling. The select engineering properties presented in Table 1 represent pilings of “typical” diameter and structural element configuration used for fender piling applications. For the fiberglass-reinforced plastic pier pilings manufactured by Seaward and PPI, the structural

TABLE 1
SELECTED ENGINEERING PROPERTIES
TIMBER AND REINFORCED PLASTIC PIER PILINGS

Physical Properties	Units	Timber Pilings	Fiberglass-Reinforced Plastic Pilings		Steel-Reinforced Plastic Pilings	
		Douglas Fir ¹ (Coastal)	Seaward ² (13-inch diameter pile with eight, 1.25- inch fiberglass rebar)	PPI ³ (13-inch diameter pile with welded steel cage reinforcement consisting of eight, 1.25-inch fiberglass rebar)	PPI ³ (13-inch diameter pile with welded steel cage with eight, #8 rebar longitudinal elements and #3 rebar spiral)	PPI ³ (13-inch diameter with 6-inch diameter, schedule 40 steel pipe core)
Modulus of Elasticity	psi	1.6×10^6	5.75×10^5	5.72×10^5	2.9×10^7	2.9×10^7
Moment of Inertia	in ⁴	140	1,402	1,402	87.93	59
Stiffness	lb-in ²	2.24×10^9	8.06×10^8	8.02×10^8	2.55×10^9	1.71×10^9
Maximum Yield Stress in Bending	psi	4,800	4,901	5,000	NA	NA

Notes:

NA Not available

psi Pounds per square inch

in⁴ Inches to the fourth power

lb-in² Pound-inch square

1 Source: National Design Specifications for Wood Construction, American Forest and Paper Association, Washington D.C.

2 Source: Seaward 1994

3 Sources: PPI 1999 and NFESC 1999

properties of a 13-inch-diameter piling with eight, 1.25-inch-diameter fiberglass structural elements are provided. For the steel-reinforced plastic pier pilings manufactured by PPI, the structural properties of (1) a 13-inch-diameter piling with a welded cage of steel consisting of eight, #8 steel rebar and a #3 spiral, and (2) a 13-inch-diameter piling with a 6-inch-diameter schedule 40 steel pipe core are provided.

During design of a pier retrofit or construction project, the structural requirement of the pilings are determined using the anticipated loads to be placed on the pier. The plastic pier piling manufacturers claim that their pilings can be designed to meet the structural requirements for many piling applications, including fender pilings and bearing piling. However, as the structural requirements increase, so do the cost of the plastic pier pilings. Because of the availability of other, lower-cost, high-load bearing material such as concrete and steel, the plastic pier pilings installed within Navy Region Southwest have primarily been used as fender pilings.

Traditionally, timber pilings have been the material of choice for fender pilings because of the high yield stress in bending and relatively low cost of wood. Recently, Navy Region Southwest has been using plastic pier pilings because of their high capacity for energy absorption and the reserve capacity after yield for accidental overload. Based on discussion with PWC Waterfront Division personnel, the lack of stiffness of the fiberglass plastic pier pilings installed within Navy Region Southwest has been a concern because the fender pilings will bend instead of absorbing the lateral load placed on them during berthing of ships. As such, fiberglass plastic pier pilings installed within Navy Region Southwest have been used primarily as secondary fender pilings.

Navy Region Southwest has recently begun to experiment with steel-reinforced plastic pier pilings as primary fender pilings. According to the manufacturer and tests conducted by NFESC, steel-reinforced plastic pier pilings with a welded steel cage have similar structural properties to wood. Fiberglass-reinforced plastic pier pilings can also be manufactured with similar structural properties to wood. These pilings combine the stiffness and rigidity of wood with the reserve capacity after yield of plastic pier pilings. Because steel-reinforced plastic pilings have only recently been installed as primary fender piling, the results of their performance in this application are currently not available.

4.1.3 Primary Objective P3

Estimate the capital and maintenance costs of replacing a single treated timber piling with a plastic fender piling.

The costs for installing and maintaining plastic pier pilings and timber pilings are presented in three categories: (1) installation costs, which include labor, consumable material (excluding the pilings), residual handling, and waste disposal; (2) piling costs, which include piling acquisition and delivery to the site; and (3) maintenance costs, which includes piling inspection and replacement.

Each cost category and associated cost elements are defined and discussed below, and serve as the basis for the estimated costs presented in Table 2. Cost data on untreated and ACZA-treated timber pilings and fiberglass- and steel-reinforced plastic pier pilings were obtained by contacting the piling manufacturers and distributors as well as PWC Waterfront Maintenance personnel.

This cost analysis assumes that a single 13-inch-diameter, 70-foot long plastic pier piling or timber piling equivalent will be installed and maintained over a 40 year period. The cost analysis also assumes that piling replacement will be due to natural degradation in the marine environment and will be at a frequency of once every 2 years for untreated timber pilings and once every 7 years for ACZA-treated timber pilings. Additionally, it is assumed that the plastic pier pilings will require replacement once every 40 years. However, the 40 year estimate is based on vendor claims and has not been proven in the field. Therefore, costs for plastic pier piling replacement at a frequency of once every 10 years are also included as a conservative estimate of piling life expectancy based on observations of plastic pier pilings at sites outside Navy Region Southwest.

Installation Costs. Installation costs will vary widely depending on the type and size of the piling project. Piling projects can vary from small piling replacement projects to new pier construction or complete retrofit projects with costs ranging from a few thousand dollars to several million dollars. Based on discussions with Doug Melland, PWC Waterfront Maintenance, installation requirements for timber and plastic pier pilings are very similar. Therefore, installation costs for timber and plastic pier pilings are assumed to be the same. For this cost analysis, installation costs have been provided

TABLE 2
COST COMPARISON
TIMBER AND REINFORCED PLASTIC PIER PILINGS

Cost Category	Timber Piling (Douglas Fir)¹		Fiberglass-Reinforced Plastic Pilings (13-Inch-Diameter)¹		Steel-Reinforced Plastic Pilings (13-Inch-Diameter)¹	
	Untreated	ACZA-Treated	Seaward (eight, 1.25-inch-diameter fiberglass)	PPI (eight, 1.25-inch-diameter fiberglass)	PPI (welded steel cage, eight, #8 rebar and #3 rebar spiral)	PPI (8-inch-diameter steel pipe core)
Installation Costs ²	\$900	\$900	\$900	\$900	\$900	\$900
Piling Costs ³	\$1,050	\$1,580	\$2,660	\$2,730	\$2,380	\$2,450
Subtotal	\$1,950	\$2,480	\$3,560	\$3,630	\$3,280	\$3,350
Average Piling and Installation Costs	\$1,950	\$2,480	\$3,460			
Annual Maintenance Costs	\$980/year	\$350/year	\$89 to \$360/year	\$91 to \$360/year	\$82 to \$330/year	\$84 to \$340/year
Average Annual Maintenance Costs	\$980/year	\$350/year	\$87 to \$350/year			

Notes:

ACZA Ammoniacal copper zinc arsenate

PPI Plastic Pilings, Inc.

¹ All costs are provided on a per piling basis.² Installation costs were provided by Navy Public Work Center, Waterfront Division.³ The piling length is assumed to be 70 feet long.

by PWC. Based on PWC's extensive experience conducting waterfront maintenance and construction projects within Navy Region Southwest, piling installation costs on a per piling basis are estimated to be \$900. This cost includes site preparation, labor, residual handling, and waste disposal. Because most pier piling retrofit projects consist of replacing pilings in kind (with similar construction material), permits are typically not required and regulatory requirements are minimal. As such, costs for permits and regulatory requirements are not included in this cost analysis.

Piling Costs. The primary factors that affect piling cost are (1) the diameter of the piling, (2) the length of the piling, (3) the type, configuration, and number of structural elements (for plastic pier pilings), and (4) number of pilings needed. This analysis compares the costs of untreated and treated timber and plastic pier pilings that are 13-inches in diameter and 70-feet long. Piling cost information was obtained by contacting timber piling distributors and plastic pier piling manufacturers. For this analysis, costs were based on the purchase of a single piling.

Based on discussions with sales representatives from J.H. Baxter (a timber piling distributor in California) and PWC Waterfront Maintenance personnel, a 70-foot long, 50-inch circumference untreated timber piling costs about \$1,050. This circumference is comparable to 13-inch diameter plastic piling because timber pilings taper from the bottom to the top. A same size timber piling treated with ACZA to a minimum of 2.5 pounds per cubic foot costs about \$1,580. These piling costs include transportation of the piling to San Diego, California.

Both Seaward and PPI were contacted to obtain cost information on fiberglass-reinforced plastic pier pilings. According to Seaward, the cost for a 13-inch-diameter fiberglass-reinforced plastic pier piling with eight 1.25-inch-diameter fiberglass structural elements is about \$38 per linear foot or about \$2,660 for a 70 foot piling. According to PPI, the cost for a 13-inch-diameter fiberglass-reinforced plastic pier pilings with eight 1.25-inch-diameter fiberglass structural elements is about \$39 per linear foot or about \$2,730 for a 70 foot piling. These costs include transportation of the piling from the manufacturer's facility to San Diego, California.

PPI was also contacted regarding the costs associated with steel-reinforced plastic pier pilings. The cost for steel-reinforced plastic pier pilings with a welded cage of steel consisting of eight, #8 steel rebar pieces and a #3 spiral is about \$34 per linear foot or about \$2,380 for a 70 foot piling. The cost for steel-reinforced plastic pier pilings using an 8-inch-diameter, schedule 40 steel pipe core is about \$35 per linear foot or about

\$2,450 for a 70 foot piling. These costs also include transportation of the piling from the manufacturer's facility to San Diego, California..

Maintenance Costs. Piling maintenance requirements typically consist of periodic inspection of the pilings for degradation and ship damage as well as replacement of the piling. Inspection of the pilings is typically conducted on an annual basis; however, the frequency will vary from base to base, depending on their specific policy. During the inspection, pilings that are damaged and require replacement are identified and reported to PWC Waterfront Maintenance. Additionally, when ship damage to a piling occurs, the damaged piling is reported to PWC Waterfront Maintenance for replacement. For this cost analysis, annual inspection costs are assumed to be insignificant relative to replacement costs and are not included in the piling maintenance costs.

Based on discussions with PWC Waterfront Maintenance personnel, untreated timber fender pilings are typically replaced at least once every 1 to 2 years because of natural degradation in the marine environment and ACZA-treated timber pilings require placement at least once every 5 to 7 years. Additional pilings will require replacement because of ship damage. However, piling replacement from ship damage is hard to quantify and predict because of the random nature of the type of damage and occurrence of the event. For this cost analysis, long-term maintenance costs for untreated and ACZA-treated timber pilings are assumed to be associated with the replacement of pilings every 2 and 7 years, respectively. Given the installation and piling costs presented above, replacement costs for an untreated timber piling are estimated to be \$1,950 every 2 years or about \$980 a year. Replacement costs for a treated timber piling are estimated to be \$2,480 every 7 years or about \$350 a year.

Because the use of plastic pier pilings is a relatively recent occurrence, long-term maintenance costs associated with plastic pier pilings are not known. However, based on the results of this study, maintenance costs appear to be limited. Of the more than 1,200 plastic pier pilings installed during the last 4 years at piers with Navy Region Southwest, none of the pilings has required replacement because of degradation from exposure to the marine environment and fewer than five have required replacement because of ship damage. Based on discussion with PWC Waterfront Maintenance, the plastic pier pilings are warranted by the manufacturer against degradation for a period of 10 years and are expected to last up to 40 years. At U.S. Naval Base Roosevelt Roads in Puerto Rico, plastic pier pilings have lasted since 1991 with no corrosion or damage. Of the 80 pilings installed at the Puerto Rico base, only one has been replaced because it was stolen from the premises. Because the actual life expectancy of the plastic pier pilings is

unknown, costs for long-term maintenance are provided as a range assuming that long-term maintenance will be limited to replacement of the plastic pier pilings once every 10 to 40 years. Given this range and the average fiberglass- and steel-reinforced plastic pier piling and installation costs of \$3,460, the average long-term maintenance costs for the plastic pier pilings are estimated to range from \$3,460 per piling over a 10 year period or about \$350 per year to \$3,460 per piling over a 40 year period or about \$87 per year.

Life-Cycle Cost Analysis. Based on the costs discussed above, a life-cycle cost comparison for timber and plastic pier pilings is presented in Table 3. The life-cycle cost analysis evaluates piling costs at 1, 2, 3, 5, 10, and 40 year intervals. For simplicity, the time cost of money or effective interest rate has been assumed to be 0 percent in this evaluation.

The initial capital cost to install a plastic pier piling is about \$1,330 to \$1,680 more than the cost of installing an untreated timber piling and \$800 to \$1,150 more than the cost of installing an ACZA-treated timber piling. However, the long-term maintenance costs of the plastic pier pilings are anticipated to be much less. Assuming a 10 year life-expectancy for the plastic pier pilings, the piling will save between \$4,520 to \$5,170 in maintenance costs or about \$450 to \$520 annually when compared to untreated timber piling maintenance costs. Given the estimated replacement cost for untreated timber pilings of \$1,970 per piling, the additional cost of installing plastic pier pilings should have a payback of less than 3 years. Using the estimated replacement cost for ACZA-treated timber pilings of \$2,480 per piling, the additional cost of installing a steel-reinforced plastic pier piling should have a payback of greater than 40 years; there is no payback on additional cost of installing fiberglass-reinforced plastic pier pilings.

Assuming a 40 year life-expectancy for the plastic pier pilings, the piling will save between \$33,880 to \$34,590 in maintenance costs or about \$850 to \$860 annually when compared to untreated timber maintenance costs. Given the estimated replacement cost for untreated timber piles of \$1,970 per piling, the additional cost of installing plastic pier pilings should have a payback of less than 2 years. The payback when compared to ACZA-treated timber pilings should be less than 5 years.

4.1.4 Primary Objective P4

Assess the pertinent federal, state, and local environmental regulatory requirements pertinent to the transport, use, storage, and disposal of plastic piling and their residuals.

TABLE 3
LIFE-CYCLE COST COMPARISON
TIMBER AND REINFORCED PLASTIC PIER PILINGS

Assumptions	Timber Piling (Douglas Fir)		Fiberglass-Reinforced Plastic Pilings (13-inch-diameter)		Steel-Reinforced Plastic Pilings (13-inch-diameter)	
	Untreated	ACZA-Treated	Seaward (eight, 1.25-inch-diameter fiberglass)	PPI (eight, 1.25-inch-diameter fiberglass)	PPI (welded steel cage, Eight, #8 rebar and #3 rebar spiral)	PPI (8-inch-diameter steel pipe core)
Installation and Piling Costs	\$1,950	\$2,480	\$3,560	\$3,630	\$3,280	\$3,350
Annual Maintenance Costs	\$980/year	\$350/year	\$89 to \$360/year	\$91 to \$360/year	\$82 to \$330/year	\$84 to \$340/year
Year 1	\$2,930	\$2,830	\$3,650 to \$3,920	\$3,720 to \$3,990	\$3,360 to \$3,610	\$3,430 to \$3,690
Year 2	\$3,910	\$3,180	\$3,740 to \$4,280	\$3,810 to \$4,350	\$3,440 to \$3,940	\$3,520 to \$4,030
Year 3	\$4,890	\$3,530	\$3,830 to \$4,640	\$3,900 to \$4,710	\$3,530 to \$4,270	\$3,600 to \$4,370
Year 5	\$6,850	\$4,230	\$4,010 to \$5,360	\$4,090 to \$5,430	\$3,690 to \$4,930	\$3,770 to \$5,050
Year 10	\$11,750	\$5,980	\$4,450 to \$7,160	\$4,540 to \$7,230	\$4,100 to \$6,580	\$4,190 to \$6,750
Year 40	\$41,150	\$16,480	\$7,120 to \$17,960	\$7,270 to \$18,030	\$6,560 to \$16,480	\$6,710 to \$16,950

Notes:

ACZA Ammoniacal copper zinc arsenate

PPI Plastic Pilings, Inc.

Regulatory authority on the use of pilings for construction projects in the waters of the State of California is primarily the responsibility of the U.S. Department of Fish and Game, State Water Resources Control Board, and California Coastal Commission. These agencies have the authority to determine which projects and materials are appropriate based on environmental, economic, and community concerns, and laws and regulations.

Over the past century, the U.S. Department of Fish and Game, Code 5650 has provided the basis for protection of the water of the state. The Code states in part:

“(a) Except as provided in subdivision (b), it is unlawful to deposit in, permit to pass into, or place where it can pass into the waters of this state any of the following:

- (1) Any petroleum, acid, coal or oil tar, lampblack, aniline, asphalt, bitumen, or residuary product, or carbonaceous material or substance
- (2) Any refuse, liquid or solid, from any refinery, gas house, tannery, distillery, chemical works, mill or factory of any kind
- (3) Any sawdust, shavings, slabs, or edgings
- (4) Any factory refuse, lime or slag
- (5) Any cocculus indicus
- (6) Any substance or material deleterious to fish, plant life, or bird life”

The first issue that must be addressed to determine if a product can be used is assurance that the proposed use of the product will not substantially adversely affect fish and wildlife resources. To determine the toxicity of the plastic pier pilings, a sample of the pilings was collected by Seaward and analyzed using the Toxicity Characteristic Leaching Procedure (TCLP) and U.S. Environmental Protection Agency test methods for metal analyses. The results of the toxicity test are presented in Table 4 (Seaward 1994). Based on the toxicity data, the use of plastic pier pilings does not appear to present any environmental concerns to fish and wildlife. Additionally, because the plastic pier pilings are constructed with inert materials (recycled plastic), there are no additional transportation, use, storage, or disposal requirements.

TABLE 4
ANALYTICAL RESULTS
TOXICITY CHARACTERISTIC LEACHING PROCEDURE FOR PLASTIC PIER PILING

Chemical Compound	TCLP Concentration (milligram per liter)
Silver	ND
Arsenic	ND
Barium	ND
Cadmium	ND
Chromium	ND
Copper	0.4
Iron	2.2
Mercury	ND
Lead	ND
Selenium	ND
Zinc	0.7

Notes:

ND Not detected above the laboratory reporting limit.

Although there is currently no written regional Navy policy on the use of treated timber piles for repairing piers, the Navy has primarily been installing untreated wood, concrete, steel, and plastic pilings for pier repairs and replacements during the last 4 to 5 years. During this period, creosote-treated timber pilings have not been used because of regulatory concerns expressed regarding the leaching of toxic chemicals from treated wood. Recently, ACZA-treated pilings have been installed at NAB Coronado. The use of ACZA-treated pilings was conducted in accordance with PWC San Diego Instruction 5090.5, which allows for the use of some treated wood as long as it complies with the American Wood Preservers' Association, Book of Standards and the Western Wood Preservers Institute, Best Management Practices for the Use of Treated Wood in Aquatic Environments. Reportedly, the Navy plans to issue a regional policy on use of treated wood in the near future.

Although Navy Region Southwest has not issued a regional policy on the use of treated wood, NFESC has prepared interim technical guidance on wood protection in the marine environment. The guidance states that the use of timber in the marine environment should be based on life-cycle economics. If timber is placed in the marine environment, it should be pressure treated according to American Wood Preservers Association Standards unless state and local regulations restrict its installation, cutting, use, or disposal.

The Navy should conduct site-specific risk assessments for each area containing a significant quantity of treated timber to determine the impact on the local marine environment. The risk assessment method may employ the software developed by the Western Wood Preservers Institute or other similar system. The assessment may also include a leachability analysis if required by the local regulatory authority (NFESC 1995).

4.2 SECONDARY OBJECTIVES

Secondary objective provided additional information that is useful, but not critical, for the evaluation of the plastic pier pilings. Five secondary objectives were selected for the plastic pier piling evaluation. The results for each secondary objective are discussed in the following subsections.

4.2.1 Secondary Objective S1

Document plastic fender piling installation and finishing parameters.

During the plastic pier pilings evaluation, the technical and administrative feasibility of using plastic pier pilings was assessed, including the plastic pier pilings installation and finishing requirements, commercial availability of services and material to install plastic pier pilings, and state and community acceptance.

Plastic pier pilings installation and finishing requirements were observed during installation of plastic pier pilings at SPAWAR Pier 160. Based on observations made during installation of the pilings, plastic pier piling installation appears to be almost identical to installing timber piles. As with timber piling installation, once the pile location is identified and wale and chock are in place, the plastic piling is dropped into place using a crane. The pile is initially held in the vertical position by a crane. Once in place, the ground crew line up the pile and the pile is released, causing it to plunge into the sea floor sediments. This procedure is called “spiking.” A driving hammer is then placed on the top of the piling and the piling is driven to the required depth. Typically, during timber pile installation, 70-foot-long timber piles are spiked and driven to bedrock. Once the piling driving is complete, excess timber piling is then cut off the top. However, because plastic pier pilings are difficult and time consuming to cut, they are typically ordered to length as determined from sounding of the mud line. This also minimizes the finishing requirements and amount of

solid waste generated during the project. Additionally, cut plastic pier pilings require sealing to protect the fiberglass and steel structural elements from corrosion and degradation.

Before installing the plastic pier pilings at Pier 160, the existing wale and chocks were removed and new wale and chocks were constructed using treated timber. The new wale and chocks were moved out an additional 12 inches to avoid driving the plastic pier pilings into old rotted timber piles left in the mud line. This allowed the consistent placement of the pilings at 8-foot intervals along the face of the pier. Thus, the construction of new wale and chocks required additional time. During installation of new plastic pier pilings, about eight piles were driven each day, which included: (1) the removal of existing pilings, wale, and chocks; (2) installation of the new pilings, wale, and chocks; and (3) attachment of the pilings to wale.

During piling installation activities at Pier 160, driving of the plastic pier piles required less than 15 minutes for each pile. Driving was conducted without the use of a drive shoe or drive cap. No noticeable damage or deformation to the top of the piling was observed after driving. However, the manufacturer recommends that a cushioned drive cap be used during driving of the pilings and a drive shoe be used when driving in dense sediments.

Based on a search of available sources of plastic pier pilings, the pilings are readily available and can be installed by local marine construction personnel with little retooling or additional training requirements. Other than the plastic piling itself, PWC Waterfront Maintenance personnel use the same tools and equipment for installing the plastic pier pilings as they do for timber pilings. The only difference is that timber pilings are typically attached to the wale using galvanized through-bolts, and galvanized collars are used to secure the plastic pier pilings to the wale.

Administratively, the plastic pier pilings are easy to procure, and since they appear to have a longer life-cycle than timber piles, their use should decrease the administrative requirements incurred by frequent replacement of pilings. Because the pilings consist of inert, 100 percent recycled material, administrative requirements associated with storage, permitting, and disposal will also be reduced. Additionally, state and local community acceptance is anticipated because of the pilings inert nature.

4.2.2 Secondary Objective S2

Estimate assets (equipment and parts) that port operations must store and maintain as a result of using alternative plastic fender pilings.

Based on discussions with PWC Waterfront Maintenance personnel, the equipment used to install the plastic pier pilings is very similar to those used to install timber pilings. As such, no additional equipment must be stored or maintained by PWC to install plastic pier pilings.

4.2.3 Secondary Objective S3

Assess the availability of plastic fender pilings.

An internet search was conducted to identify manufacturers of plastic pier pilings. Two manufacturers were identified that provide plastic pier pilings: (1) Seaward and (2) PPI. Seaward manufactures fiberglass-reinforced plastic pier pilings and PPI manufactures both fiberglass- and steel-reinforced plastic pier pilings. Seaward manufactures their plastic pier pilings in Virginia, while PPI manufactures their pilings in southern California. Contact information for Seaward and PPI is provided in Section 2.4.

4.2.4 Secondary Objective S4

Document the potential for plastic fender pilings to reduce wear or adverse impacts on the special coatings of ships hulls.

The majority of plastic pier pilings installed within Navy Region Southwest are used as secondary fender pilings and are protected by camels. As such, the plastic pier pilings sustain infrequent contact with berthing ships. Given the infrequent contact with ship hulls, a direct evaluation of the pilings ability to reduce wear on ships hulls was not possible during this study. However, based on the measured coefficient of friction of the pilings outer plastic matrix of approximately 0.20, the plastic pilings should decrease the amount of wear on ships hulls.

4.2.5 Secondary Objective S5

Document the frequency and degree of maintenance required for upkeep of the plastic pilings.

Before installation of plastic pier pilings, the pilings should be handled with care to ensure they are not damaged. According to the manufacturers, pilings should be stored above the ground on blocks that are shaped or padded to prevent scarring or sagging of the pilings. Furthermore, storage racks should be arranged to permit air circulation, and pilings should be covered from direct sunlight. Pilings should be moved using a crane or forklift. During transport, storage, and installation of the plastic pier pilings, care should be taken not to drop, break, bruise, or penetrate the outer surface of the piling with tools.

Once installed, the maintenance requirements are dependent on the intended use of the piling. For example, secondary fender piles are typically used to keep floating debris from going beneath the pier and to protect the pier structure from occasional impacts of berthing ships. As such, the amount and intensity of wear on the pilings is significantly reduced as compared to primary fender pilings. Therefore, pilings used as secondary fender pilings will have significantly lower maintenance requirements and costs over time. Primary fender pilings on the other hand are exposed to sharp concentrated loads that occur on a variable basis, depending on the amount of pier use and type of ship berthing. For these pilings, the amount of abrasion, chipping, and spalling is significantly increased, which leads to more frequent maintenance and replacement as well as higher maintenance costs.

Typically, maintenance of timber and plastic fender pilings consists of periodic inspection of the pilings for degradation and ship damage. Once a piling has lost its structural integrity, it is typically replaced. The long-term maintenance costs to replace timber pilings is a significant financial concern, especially given the expected life-span of 1 to 1½ years for the untreated timber piles currently being used for marine applications within Navy Region Southwest. Although the long-term maintenance costs and life-span expectancy for plastic pier pilings has not been determined, the data collected to date suggest that their life expectancy when used as secondary fender pilings is significantly longer than that of timber pilings.

Of the more than 1,200 plastic pier pilings installed during the last 4 years at piers within Navy Region Southwest, none of the pilings has required replacement because of degradation from exposure to the marine environment and five have required replacement because of ship damage. In addition, based on observations made during inspection of the plastic pier pilings and discussions with PWC Waterfront Maintenance personnel and Navy Pier Maintenance personnel, the maintenance requirement associated with the plastic pier pilings appears to be limited. Other than the transverse cracks observed on many of

the pilings, plastic pier piling users indicate that they are generally impressed with the pilings' performance and have not had maintenance problems.

5.0 CONCLUSIONS

This plastic pier pilings evaluation was conducted under NELP to assess the durability, strength, cost, and environmental integrity of the pilings. The high maintenance and replacement costs of timber and environmental concerns over treated timber pilings makes finding an appropriate piling alternative an important aspect of NELP's pollution prevention program. The conclusions of the plastic pier pilings evaluation, including the pilings' performance, installation, maintenance, and cost characteristics are summarized below.

5.1 PERFORMANCE CHARACTERISTICS

Plastic pier pilings offer facilities managers and dock designers an alternative to traditional creosote and other chemically treated timber pilings for fendering and certain structural applications. Plastic fender pilings have a high capacity for energy absorption and the reserve capacity after yield for accidental overload. Additionally, the pilings are constructed of inert materials, thereby minimizing environmental concern and liability. The pilings can be designed and manufactured to meet the structural requirements for a variety of piling applications. However, it should be noted that the performance of the plastic pier piling will vary with each installation because of the numerous variables that affect piling performance.

To date, Navy Region Southwest has primarily used the plastic pier pilings as secondary fender pilings to protect pier structures from occasional impacts of berthing ships and to keep floating debris from going beneath the piers. Pier maintenance personnel have reported no performance problems with these secondary plastic fender pilings, with the exception of a manufacturer defect that caused cracking of the outer plastic matrix of the pilings. The defect has been corrected and no other performance problems have been identified. Recently, several piers have replaced their timber primary fender pilings with steel-reinforced plastic pier pilings. However, installations of these pilings is too recent to evaluate the performance of the plastic pier pilings as primary fenders.

5.2 INSTALLATION REQUIREMENTS

Based on the results of this evaluation, installation of plastic pier pilings is very similar to installing timber piles and can be utilized by local marine construction personnel with little retooling or additional training requirements. Other than the plastic piling itself, the same tools and equipment used to install and finish timber pilings can be used for installing plastic pier pilings. The pilings are constructed with inert, 100 percent recycled plastic and are readily available from two manufacturers. Because the pilings consist of inert material, administrative requirements associated with storage, permitting, and disposal are reduced, and state and local community acceptance of marine retrofit project is enhanced.

5.3 MAINTENANCE REQUIREMENTS

Because use of plastic pier pilings is a relatively recent occurrence, long-term maintenance requirements and costs associated with plastic pier pilings are unknown. However, based on the results of this study, maintenance costs appear to be minimal. Of the more than 1,200 plastic pier pilings installed during the last 4 years at piers within Navy Region Southwest, none of the pilings has required replacement because of degradation from exposure to the marine environment, and fewer than five have required replacement because of ship damage. According to the manufacturer, the plastic pier pilings are warranted against degradation for a period of 10 years and may last as long as 40 years or more if not damaged by berthing ships. Although the actual service life of the plastic pier pilings is unknown, the results of this study suggest that it is much longer than untreated and ACZA-treated timber pilings, which have a life expectancy of 1 to 1½ years and 5 to 7 years, respectively. The longer service life of plastic pier pilings should decrease the administrative requirements and maintenance costs associated with frequent replacement of timber pilings.

5.4 COST ANALYSIS

The costs for installing plastic pier pilings and untreated timber pilings were compared for three cost categories: (1) installation costs, (2) piling costs, and (3) maintenance costs. Installation of untreated timber and plastic pier pilings was estimated to be \$900 per piling. Untreated timber piling costs were estimated at \$1,050 per piling, ACZA-treated timber pilings at \$1,580 per piling, and plastic pier pilings ranged from \$2,380 to \$2,730 per piling. Annual piling maintenance costs were estimated to be \$980 for

untreated timber pilings and \$350 for ACZA-treated timber pilings. Annual piling maintenance costs for plastic pier pilings assuming a 10 year life expectancy were estimated to range from \$330 to \$360 per piling. Assuming a 40 year life expectancy, annual plastic pier piling maintenance costs were estimated to range from \$82 to \$91 per piling.

Based on the cost data presented above, the initial capital cost to install a plastic pier piling is about \$1,330 to \$1,680 more than the cost of installing an untreated timber piling and \$800 to \$1,150 more than installing an ACZA-treated timber piling. However, the long-term maintenance costs of the plastic pier pilings are much less. Assuming an estimated plastic pier piling life expectancy of 10 years, the additional cost of installing plastic pier pilings will have a payback of less than 3 years versus untreated timber pilings and a payback of greater than 40 years versus ACZA-treated timber pilings. Assuming an estimated plastic pier piling life expectancy of 40 years, the additional cost of installing plastic pier pilings will have a payback of less than 2 years versus untreated timber pilings and 5 years versus ACZA-treated timber pilings.

6.0 REFERENCES

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